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(71) Applicant(s)
Smith International Incorporated

(Incorporated in USA - Delaware)

PO Box 60068, 16740 Hardy Street, Houston, Texas 77205-0068, United States of America

(72) Inventor(s)
Madapusi K Keshavan
Kuttaripalayam T Kembaiyan
Wayne C Quantz

(74) Agent and/or Address for Service
Saunders & Dolleymore
9 Rickmansworth Road, WATFORD, Herts, WD1 7HE, United Kingdom

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(56) Documents Cited
GB 1475412 A GB 1291294 A GB 1290986 A
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ONLINE DATABASES : WPI, CLAIMS

(54) **Hardfacing for rock drilling bits**

(57) Hardfacing a metal substrate of a rock bit renders the substrate surfaces of the rock bit more resistant to erosion, corrosion and substrate cracking while performing in an earthen formation comprises bombarding the surfaces with a thermal spray of entrained fine particles of a cermet based composition at a velocity in excess of 600 m/sec. The resultant coating of the cermet based composition has a tensile bond strength in excess of 1400 kg/cm^2 that results in an increase of the strain to fracture of the rock bit surface. The layer of hardfacing has a resistance to severe service environments of high strain and shock tolerance as well as a higher load carrying capacity. The coating may have a hardness of at least 900 kg/mm^2 Vickers Hardness Number and may comprises a metal carbide with a metal binder.

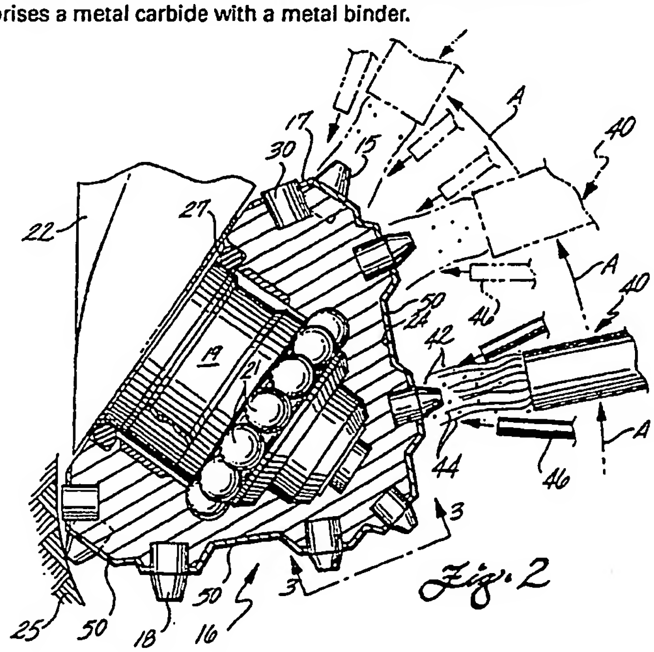

Fig. 2

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

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Fig. 1

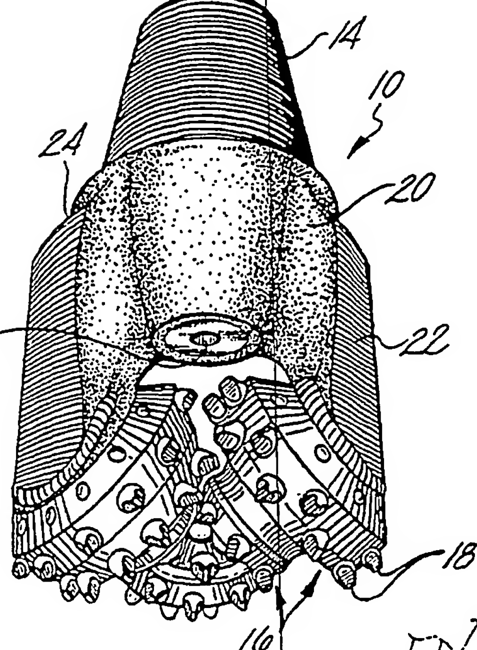
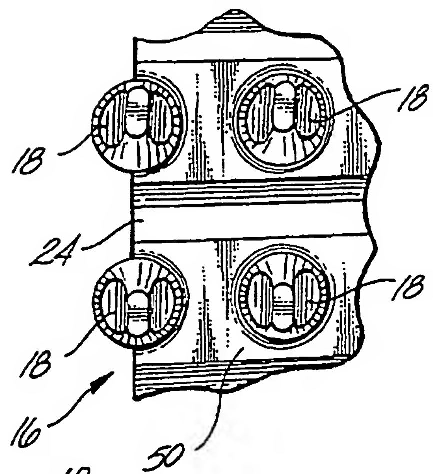


Fig. 3



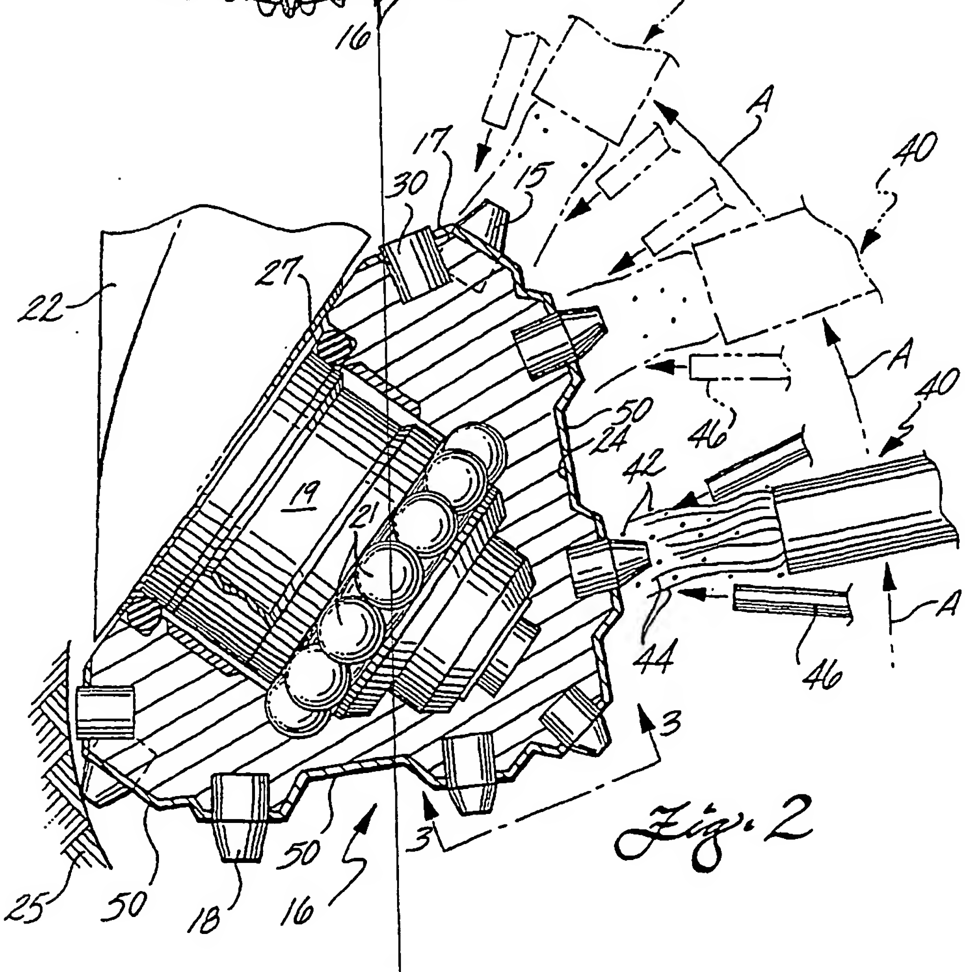


Fig. 2

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HARDFACING FOR ROCK DRILLING BITS

This invention relates to hardfacing of metallic surfaces of rock bit components such as rotary cones, rock bit legs supporting the cones and the exposed surfaces surrounding the cutters mounted within the face of a drag type rock bit.

More particularly, this invention relates to the application of a hardfacing coating to the exposed surfaces of steel rotary cones and their supporting legs of rotary cone rock bits. The hardfacing coating also has an application for the cutting face surrounding diamond cutters mounted within the face of diamond drag rock bits and the like.

Hardfacing of rock drilling bit cones for the purpose of inhibiting cone erosion and wear during known harsh rock drilling conditions has been done before with varying degrees of success.

For example, U.S. Patent Numbers 4,708,752 and 4,781,770 teach the use of lasers to either harden the surface of the rotary cones of a rock bit or entrain a stream of hardfacing material into the laser beam to apply a layer of hardfacing material to the surface of the rotary cones. Both of the foregoing patents are incorporated herein by reference.

U.S. Patent No. 4,685,359 describes a method of manufacturing a steel bodied bit in which a hardfacing of

a highly conformable metal cloth containing hard, wear resistant particles is applied to rock bit faces and to the interior of nozzle openings and the like. The cloth known as "CONFORMA CLAD" manufactured by Imperial Clevite, Inc. of Salem, Indiana must first be cut to shape to fit the component to be hardfaced prior to brazing the cloth to the workpiece; a time consuming and difficult process.

There is a disadvantage in foregoing method in that the cloth material, when it is metallurgically attached to the workpiece in a furnace, changes the physical properties of the base material to the detriment of the finished product.

Thus, an improved method of hardfacing of rock bit cones and the like is disclosed that incorporates advanced hardfacing materials and application methods.

A rock bit for drilling boreholes in an earthen formation has at least some of its surfaces to be exposed to the earthen formation hardfaced to resist erosion while performing in the earthen formation. The hardfacing comprises a layer of hard particles thermal sprayed onto the surfaces of the rock bit. Preferably, the particles comprise a metal carbide with a metal binder wherein the coating has a hardness of at least 900 Kg/mm^2 Vickers Hardness Number.

Preferably, the layer of hard particles is thermal sprayed onto the surfaces of the rock bit at a velocity in excess of 600 m/sec. The layer of hard particles has a tensile bond strength in excess of 1400 kg/cm^2 that results in an increase of the strain to fracture of the rock bit surfaces through residual compressive stress.

The preferred method of applying the coating is by way of a detonation gun process to apply hardfacing material to rock bit components. Low temperature application of the coating maintains residual stress retaining tungsten carbide inserts interference fitted

within sockets formed in a rock bit cone surface. The bombardment of the insert cutters during the detonation gun application of the hardfacing material enables the inserts to withstand higher compressive loads under operating conditions.

Hydrogen embrittlement is minimized by application of tungsten carbide cermet utilizing the detonation-gun process. Hydrogen embrittlement is a process whereby there is an invasion of the hydrogen ion into the highly stressed carburized steel. A detonation gun is utilized to apply a tungsten carbide based powder at a very high velocity on a substrate such as a steel cone for a rotary cone rock bit. Prior to the detonation-gun process, the surface of the cones of a rock bit is preferably grit blasted and degreased prior to coating. Grit blasting roughens the surfaces and renders it slightly uneven which leads to better bonding of the coating to the cone surfaces. The maximum instantaneous surface temperature on the cone shell while applying the coating is maintained as los as about 200°C by, for example, impinging a stream of liquid carbon-dioxide or other refrigerant fluid unto the cone. Other mixtures of fluids, such as nitrogen, could be used for improved heat dissipation. The thickness of the coating is between 0.125 and 0.5 mm on the cone shell. The coating thickness could vary depending on the substrate and particle materials, substrate geometry and application.

An unexpected benefit of the detonation gun process is the alleviation of cone cracking by the inducement of compressive residual stresses to the cone surfaces. The detonation-gun process is especially useful in alleviating those cracks that occur between tungsten carbide inserts pressed into the cones that had, heretofore, plagued the rock bit industry.

The above noted features and advantages of the present invention will be more fully understood upon a study of the following description in conjunction with the detailed drawings wherein:

FIGURE 1 is a perspective view of a typical three cone rock bit;

FIGURE 2 is a cross-section of one of the rotary cones undergoing the hardfacing application process; and

FIGURE 3 is a view taken through 3-3 of Figure 2 illustrating a portion of the hardfaced surface of the cone adjacent to each of the tungsten carbide inserts retained therein.

Boreholes are commonly drilled with rock bits having rotary cones with cemented carbide inserts interference fitted within sockets formed in the cones. A typical rock bit generally designated as 10 has a steel body 20 with threads 14 formed at an upper end and three depending legs 22 at a lower end. Three cutter cones generally designated as 16 are rotatably mounted on the three legs 22 at the lower end of the bit body 20. A plurality of, for example, cemented tungsten carbide inserts 18 are press-fitted or interference fitted into insert sockets formed in the cones 16. Lubricant is provided to the journals 19 (Fig. 2) on which the cones are mounted from each of three grease reservoirs 24 in the body 20.

When the rock bit is employed, it is threaded unto the lower end of a drill string and lowered into a well or borehole (not shown). The bit is rotated by a rig rotary table with the carbide inserts in the cone engaging the bottom of the borehole 25 (fig. 2). As the bit rotates, the cones 16 rotate on the bearing journals 19 cantilevered from the body and essentially roll around the bottom of the borehole 25. The weight on the bit is applied to the rock formation by the inserts 18 and the

rock is thereby crushed and chipped by the inserts. A drilling fluid is pumped down the drill string to the bottom of the hole 25 and ejected from the bit through nozzles 26. The drilling fluid then travels up the annulus formed between the exterior of the drill pipe and the borehole wall carrying with it the rock chip detritus. In addition the drilling fluid serves to cool and clean the cutting end of the bit as it works in the borehole.

With reference now to Figure 2, the lower portion of the leg 22 supports a journal bearing 19 by a plurality of cone retention balls 21 confined by a pair of opposing ball races formed in the journal and the cone. The cone includes an annular heel row 17 positioned between the gage row inserts 15 and bearing cavity 27 formed in cone 16. A multiplicity of protruding heel row insert cutters 30 are about equidistantly spaced around the heel row 17. The protruding inserts 30 and the gage row inserts 15 co-act to primarily cut the gage diameter of the borehole. The multiplicity of remaining inserts in concentric rows crush and chip the earthen formation as heretofore described.

Much of the erosion of the cones typically occurs between the gage row and the heel row inserts 15 and 30. As heretofore described, this type of erosion may result in damage to or loss of the inserts and cone cracking, particularly between the inserts. In highly erosive environments, the whole of the cone body is subjected to severe erosion and corrosion.

A layer of hardfacing (hard particles) or coating 50 is thermal sprayed unto a rock bit surface and the hard particles are selected from the group consisting of a metal carbide with a metal or metal alloy wherein the coating has a hardness of at least 900 Kg/mm^2 Vickers Hardness Number (VHN).

The hardfacing coating 50 on cone 16 illustrated in Figures 2 and 3 is preferably applied by a thermal spray method. The thermal spray method shown in schematic form

in Fig, 2 and generally designated as 40 is preferably applied by a detonation spraying apparatus manufactured by Praxair Surface Technologies, Inc., Indianapolis, Indiana and is called, the SUPER D-GUN (trademark) process. The foregoing process heats fine powders such as tungsten carbide to near their melting points and projects them at extremely high velocities against the surface to be coated (in the present example, the surface 24 of cone 16). Particle velocities frequently exceed 600 m/sec. Impingement of the entrained tungsten carbide or other desirable mixture of hard particles 42 into surface 24 of the steel bodied cone 16 results in a substantially metallurgical bond that is unparalleled in the industry.

The layer of hard particles has a tensile bond strength in excess of 1400 kg/cm^2 that results in an increase of the strain to fracture of the rock bit surfaces through residual compressive stress. The residual compressive stress substantially increases the strain-to-fracture of the coatings 50 mechanically bonded to the surface 24 of cone 16.

Typically, the coating thicknesses range from about 0.125 to 0.5 mm. on the cones 16 and the hardness ranges around 1100 Kg/mm^2 (VHN).

The SUPER D-GUN apparatus 40 shown in Figure 2 in schematic form is preferably aligned 90 degrees to the surface 24 of the cone 16. The nozzle of the apparatus 40 emits rapid pulses of hot gases 44 at very high velocities that entrains, for example, powdered tungsten carbide or tungsten carbide composite 42 therein. A fluid substance such as liquid carbon dioxide 46 cools the cone during the thermal spray process thereby preventing the cones from heating above about 200°C. The substrate temperature can be controlled by adjusting the coolant velocity and geometry. This method of controlling the temperature of the cones prevents degradation of the interference fit of the inserts retained within sockets formed in the cone 16 during the thermal spray process.

The cones 16 are preferably cleaned and grit blasted prior to the thermal spray process. This process results in a slightly uneven cone surface 24 resulting in better bonding of the tungsten carbide to the surface. The surface roughness of the cone after grit blasting is typically 200 to 300 microinches AA (5 to 8 micrometers).

While it is illustrated in Figure 2 with the thermal spray apparatus 40 moving to different positions "A" thereby maintaining the nozzle of the apparatus approximately 90° to the surface 24; the reverse would be more typical. The cone (separated from the journal 19) is mounted to a moveable fixture (not shown) and the fixture with attached cone is moved relative to the fixed thermal spray apparatus 40.

Figure 3 depicts the finished hardfaced surface 50 that surrounds each of the inserts 18, the hardfacing material (tungsten carbide) is tightly bound to the surface 24 and immediately adjacent to each of the inserts 18.

Materials suitable for hard coating the exposed surfaces of the rock bit cone include tungsten-chromium-nickel-carbon composite, tungsten-chromium-cobalt-carbon composite, tungsten carbide combined with either cobalt or nickel, metal or ceramic.

The uniform application of the hardfacing material through the use of the SUPER D-GUN process assures an erosion resistant surface as well as a means to essentially prevent cone cracking because of the residual compressive stresses on the outer surface of the cones.

The detonation gun process comprises carefully measured gases, usually consisting of oxygen and acetylene that are fed into a barrel of the gun along with a charge of fine tungsten carbide-based powder. The preferred hardfacing powder is designated SDG 2040 and is developed by Praxair Surface Technologies, Inc., Indianapolis, IN. The SDG 2040 coating is mainly a mixture of tungsten carbide with 15 wt % cobalt binder. The gas is ignited in

the D-GUN barrel and the resulting detonation wave heats and accelerates the powder as it moves down the barrel. The gas velocity and density are much higher than in a conventional detonation gun. The powder is entrained for a sufficient distance for it to be accelerated to its extraordinary velocity. A pulse of inert nitrogen gas is used to purge the barrel after each detonation. The process is repeated many times per second. Each detonation results in the deposition of a circle (pop) of coating material a few micrometers thick on the surface 24 of the rock bit cone 16. The total coating, of course, consists of several overlapping pops.

Precise, fully automated, pop placement results in a very uniform coating thickness of the hardfacing material 50 and a relatively smooth, planar surface on the cones 16. Moreover, the SUPER D-GUN process minimizes hydrogen embrittlement as heretofore described.

It will of course be realized that various modifications can be made in the design and operation of the present invention without departing from the spirit thereof. For example, it is feasible to utilize various ceramics or metals with the thermal spray detonation process without departing from the scope of this invention. Thus, while the principal preferred construction and mode of operation of the invention have been explained in what is now considered to represent its best embodiments, which have been illustrated and described, it should be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

CLAIMS

1. A rock bit for drilling boreholes in an earthen formation, the rock bit having at least some of its surfaces to be exposed to the earthen formation hardfaced to resist erosion while performing in the earthen formation, the hardfacing comprising:

a layer of hard particles thermal sprayed onto the surfaces of the rock bit, the particles comprising a metal carbide with a metal binder wherein the coating has a hardness of at least 900 Kg/mm^2 Vickers Hardness Number.

2. A rock bit for drilling boreholes in an earthen formation, the rock bit having at least some of its surfaces to be exposed to the earthen formation hardfaced to resist erosion while performing in the earthen formation, the hardfacing comprising:

a layer of hard particles thermal sprayed onto the surfaces of the rock bit at a velocity in excess of 600 m/sec, the layer of hard particles having a tensile bond strength in excess of 1400 kg/cm^2 that results in an increase of the strain to fracture of the rock bit surfaces through residual compressive stress.

3. A method for hardfacing an exposed metal surface of a rock bit to render the surface of the rock bit more resistant to erosion while performing in an earthen formation comprising the steps of:

bombarding the surface with a thermal spray of entrained fine hard particles at a velocity in excess of 600 m/sec and coating the surfaces with a layer of such hard particles, the coating having a tensile bond strength in excess of 1400 kg/cm^2 that results in an increase of the strain to fracture of the rock bit surfaces through residual compressive stress, and a hardness of at least 900 Kg/mm^2 Vickers Hardness Number.

4. The method as set forth in Claim 3 wherein the surfaces are bombarded with a thermal spray of hard particles exiting from a nozzle formed by a detonation gun, the nozzle being directed about ninety degrees to the surface of the rock bit to be hardfaced with the layer of hard particles.

5. The method as set forth in either one of Claims 3 or 4 wherein the surfaces of the rock bit to be hardfaced are rotary cutter cones of a rotary cone rock bit.

6. The method as set forth in Claim 5 wherein the cutter cones contain a multiplicity of strategically positioned tungsten carbide inserts retained within sockets formed in the cones, the cones being bombarded by the detonation gun with the inserts secured in the cones, the hardfacing serving to inhibit erosion and corrosion around the inserts thereby minimizing loss or destruction of the inserts as the rock bit works in a borehole.

7. The method as set forth in any one of Claims 3, 4 or 5 further comprising the step of cooling the surface while applying the thermally sprayed coating.

8. The invention as set forth in any of the preceding claims wherein the layer of hard particles is selected from the group consisting of tungsten-chromium-nickel-carbon composite and tungsten-chromium-cobalt-carbon composite.

9. The invention as set forth in any of the preceding claims wherein the hard particles is a fine powder of tungsten carbide combined with either cobalt or nickel.

10. The invention as set forth in any of the preceding claims wherein the hard particles comprise a metal.

11. The invention as set forth in any of the preceding claims wherein the hard particles comprise a ceramic.

12. The invention as set forth in any of the preceding claims wherein the thickness of the layer of hard particles on the surface is between 0.125 and 0.5 mm.

13. The invention as set forth in any of the preceding claims wherein the hardness of the layer of hard particles is at least 900 Kg/mm^2 Vickers Hardness Number.

14. A rock bit substantially as described herein with reference to the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

-12-

Application number	GB 9405340.2
Search Examiner	P G BEDDOE
Date of completion of Search	29 JUNE 1994
Documents considered relevant following a search in respect of Claims :-	1 AND IN PART 8-14

Relevant Technical Fields

(i) UK Cl (Ed.M) C7F (FGA, FGZ)

(ii) Int Cl (Ed.5) C23C (4/06, 4/08, 4/10); E21B 10/46

Databases (see below)
(i) UK Patent Office collections of GB, EP, WO and US patent specifications.

(ii) ONLINE DATABASES: WPI, CLAIMS

Categories of documents

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&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X	GB 1475412	(BOSCH) see especially page 1 line 92 - page 2 line 4	1,9
X	GB 1291294	(RAMSEY) see especially page 3 lines 30-40	1,8,9
X	GB 1290986	(SULZER) see especially page 2 lines 22-23	1,8,9
X	GB 972414	(DEUTSCHE) see especially Example 6	1,9
X	GB 874463	(UNION CARBIDE) see especially page 2 lines 35-54	1,8,9
X	US 5141821	(STARCK) see especially column 2 lines 44-62	1
X	US 5126104	(GTE) see especially Example 1	1,9
X	US 4781770	(SMITH INTERNATIONAL) see especially column 7 lines 7-20	1,9
X	US 4173457	(ALLOYS) see especially column 2 lines 13-23; column 3 lines 1-30	1,9

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